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Sustainable Production and Diversification of Yam (*Dioscorea* spp.) in Dryland Conditions in Jiguani, Granma Province

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Abstract

Context: The negative impacts of short and long-term droughts in recent decades in the municipality of Jiguani, Granma province, Cuba, threaten people's well-being and stable farming development significantly.
Aim: This paper aimed to foster sustainable diversification and production of yam in dryland conditions in the municipality of Jiguani, using biotechnological seeds. The trial was conducted on urban, suburban, and household farms in the municipality of Jiguani. This area was chosen as it is a predominantly agricultural municipality where yam (Dioscorea spp.) has been traditionally cultivated. In recent years, this crop has withstood long droughts that caused the depletion of most water supply sources.
Methods: The main biotechnological innovation consisted in the implementation of accelerated yam seed production technology, through the combination of biotechnological and conventional methods to increase the sustainable propagation of different clones (Caballo, Criollo, Chino Blanco, Caraqueño, Blanco de Guinea, Papa), along with a relevant awareness creation and training program locally, that promotes local actor engagement articulation.
Results: The results found helped implement the certified yam seed technology through biotechnological techniques satisfactorily, based on sustainable management between 2000 and 6000, in 2018, covering a total area of 0.6 ha (6000 plants), thus contributing to local development. Finally, the organoleptic analysis helped define the most promising clones for production and sale in dry-land conditions.
Conclusions: The sustainable diversification and production of yam in dry-land conditions in the municipality of Jiguani, using biotechnological seeds was achieved.

Keywords: *sustainable agriculture, biotechnological innovation, certified seeds, local development.*

Introduction

The promotion and support to the knowledge and expertise of actors that conduct specific actions against droughts, farm productions, and sustainable water use in agriculture is the road to follow to meet the challenges of agriculture and the means of subsistence posed by climate change (FAO, 2017).

Crop drought has been acknowledged as a "silent disaster" that causes considerable impacts on farming systems, such as crops, grasslands, livestock, and arable land. The main causes arise from the lack of atmospheric humidity, the insufficient number of rain-producing systems or the persistence of strong subsidence, or the combination of some of these factors, which must be studied in the context of the general atmospheric circulation.

In Cuba, several drought events have occurred, affecting almost all the country with millions in losses due to the impact on agriculture and environmental ecosystems. Hence, the causes, behavior, and consequences of such phenomena should be studied to lay out policies and strategies to fight it, and to establish early warning advisory to reduce and mitigate impacts and ensure the environmental sustainability and food safety.

The negative impact of persistent and significant short and long-term drought events of recent decades in Jiguani has become a major obstacle to ensure the well-being of the population and a stable economic development, particularly farming (Lapinel, 2011).

Worldwide, croplands have been stricken by drought events, one of the most relevant constraints of farm productions, as millions of hectares have high levels of aridity (Frahm et al., 2004).

Hence, this paper focuses on the search for alternatives to counteract the negative effects of droughts in agriculture, using tolerant crops, such as yam (*Dioscorea* spp).

Yam (*Dioscorea* spp.) produces edible tubers part of the Caribbean diet, which explains the huge demand for this item in the market (Perez et al., 2015). It is highly significant for food safety, since it has excellent nutritional characteristics and great adaptability to different edaphoclimatic conditions that contribute to the high productivity (Borges et al., 2016).

This crop can easily adapt to the different edaphoclimatic conditions of the nation; it can be planted in urban and suburban areas of towns and cities, with high yields. It requires little input, and can grow in any space, especially in the marginal areas, by fences or borders of large farmlands, plots, and household gardens.

By 2014, a team from the Municipal University of Jiguani (CUMJ), together with the local urban farm authorities and the guidance of the yam research team from the Center for Plant Biotechnology (CEBVEG), the University of Granma, has been working on the implementation of an accelerated production of the certified yam seed locally, combining biotechnological and traditional methods to restore a marginalized and orphan crop for over 40 years whose resistance to droughts has been demonstrated.

In the municipality, the coordinated research through the Program of Agricultural Biotechnology has permitted the standardization of *in vitro* yam propagation techniques to contribute to human nutrition, which are water-stress tolerant. It has awaken the farmers' interest in it due to the advantages of these systems, such as uniformity of the plant material, vigor, propagation speed, high number of regenerated plants (Ramos et al., 2015), and the introduction of new promising clones in dryland, both commercial and originally from this region.

This paper aimed to foster sustainable diversification and production of yam in dryland conditions in the municipality of Jiguani, by implementing the most recent advances of biotechnological innovation for the production of a certified yam seed at the CEBVEG, in collaboration with the CUMJ.

Materials and Methods

The experiment was conducted on urban, suburban, and family farms in Jiguani, Granma, Cuba, as it is a predominantly agricultural area with a tradition in the production of yam (*Dioscorea* spp.), which has withstood a prolonged drought of five years, as most water supply sources (wells) have dried up.

Plant materials

Healthy yam (*Dioscorea* spp.) tubers from *in vitro* plants cultivated along the crop's cycle (9 months) at the certified seed bank of CEBVEG (Table 1). The clones were introduced in urban and suburban farms, and family gardens under dryland conditions, in the municipality of Jiguani.

Table 1. Healthy yam (*Dioscorea* spp.) tubers introduced in urban, suburban, and family gardens under dry-land conditions, in the municipality of Jiguani, province of Granma, Cuba

Species	Clone
D. alata	Criollo blanco
D. alata	Caraqueño
D. alata	Chino blanco
D.rotundata	Blanco de guinea
D. esculenta	Papa

Urban agriculture

The introduction and diversification of this crop began in 2014 at Las Marianas farm, particularly clones Criollo, Chino blanco, Caraqueño, Papa, Blanco de guinea.

Suburban agriculture

It started in 2014 at the Gabriel Valiente Cooperative for Credits and Services (CSS), using clones Criollo, Chino blanco, Caraqueño and Papa.

In 2018, this technological innovation (Borges & Reyes, 2018) was introduced at the Jose Rosabal and Jose Reyes CCSs, particularly clones Criollo, Chino Blanco, Blanco de guinea and Papa. The yam was planted in April (2 x 0.5), alternating with cassava clones (2 x 1) for one year and a half. It had been previously established in October for use as a tutor, which is one of the main elements of sustainable and feasible innovation to promote its development by farmers.

Household agriculture

The participatory introduction and diversification of yam in family gardens took place in 2014. By 2019, 30 families had cultivated several different clones of yam in their gardens (Criollo, Papa, Caraqueño, Chino Blanco, and Blanco de guinea), for self-consumption.

Results and discussion

Implementation of the technological innovation

Introduction of new clones

The main novel element of this technological innovation was the introduction of 5 new clones in Jiguani, with valuable productive, nutritional, and culinary potentialities, and resistant to droughts.

Creation of local awareness and training capacities

The diversification and sustainable production of the crop came along an important awareness creation program and training, locally, delivered to the small farmers, technicians, decision-makers, direct and indirect actors, and students to acquire the new biotechnological technique for the crop establishment, handling, propagation, and spreading on urban and suburban farms, as a way of increasing the crop's sustainable production (Figure 1).

Overall, 700 people from different important local sectors received the training and gained consciousness on how to introduce the biotechnological innovation onto urban, suburban, and family farms, in Jiguani, in 2014-2019.

Innovation is the key element of development strategies, defined as a dynamic interactive process that unites agents, such as farmers, organizations, state institutions, and agricultural research and training institutions. The systematic ties and interaction among actors, as well as the economic and institutional infrastructure developed in every country determine the possibility of advancing toward an entrepreneurial and innovative culture within local development (Rojas-Meza, 2015).

Fig. 1. Discussion workshop for the introduction and diversification of drought-resistant yam, with the participation of decision-makers and farmers, in Jiguani.

In that sense, Dayanna-Ortega et al. (2017) and Vallejo et al. (2017) noted that the first step to achieve ecologically sustainable productive results locally, the actors must be trained at every level to encourage understanding of the organizational principles performed by the ecosystems through evolution, whereas Borges & Reyes (2018) were able to train and create awareness 914 from different relevant sectors in the country, to promote the successful implementation of the technological innovation to yam in urban, suburban, and family agriculture in Cuba, in 2014-2018.

Survival, vegetative development and crop yields of engineered seeds

The seeds supplied conferred over 98% survival in field conditions, vigorous vegetative development (Figure 2) free from pests, and satisfactory crop yields. The number of certified seeds was increased thanks to sustainable management, from 2000 in 2014, to 6000 in 2018, totaling 0.6 ha (6000 plants), with an average crop yield of 10-12 t/ha (1-1.2 kg/plant, depending on the clone used under dryland conditions.

Fig. 2. Vigorous vegetative development of plants from engineered seeds at 5 months of cultivation under dry-land conditions, in suburban plots, in Jiguani.

These yields (10-12 t/ha) were higher than the ones achieved using the traditional seeds (6-8 t/ha), which demonstrated the sustainability and tolerance of the crop based on the engineered yam seed under dry-land conditions.

However, Acevedo et al. (2015) said that the current water availability in the world derives from scarcity, overexploitation, and pollution, being a constraint for sustainable crop development.

Comparable results to this practical innovation in the socio-economic and productive areas have been attained by Borges & Reyes (2018), which have stimulated satisfactory implementation of sustainable farming practices, and its local extension on urban, suburban, and family cropland in Cuba. These authors were able to introduce five new clones, three of them commercial (Blanco de guinea, Belep, Papa) and two of them endogenous (Criollo and Chino blanco), with significant productive, nutritive, and cooking potentialities. They also achieved survival percentages above 95% in the dryland, which permitted a vigorous vegetative development, free from pests, and around 15 t/ha crop yields estimated.

Borges et al. (2018), using the certified yam seed from cultivated *in vitro* plants in the field showed over 97% survival. From the first production cycle, the tubers from the engineered seeds showed higher yields than the uncleaned conventionally propagated seeds (5 kg from the engineered seed to 1.5 kg of the traditional seed), as it has high genetic, physiological and sanitary values, with renewed traits.

Organoleptic analysis

The organoleptic analysis for the inclusion of different boiled yam clones in the diet (Table 2) covered different dishes and combinations with animal protein, egg, chicken, pork, lamb, and beef. In all the cases, the best results were found in Criollo, Chino Blanco, and Blanco de guinea, followed by Caraqueno and Papa.

Similar results were achieved by Hidalgo (2014), upon a characterization of the nutritional quality of yam tubers (D*ioscorea* spp.) through different analysis techniques, with the highest values observed in Chino blanco (70%), as excellent and 30% as good, followed by Criollo and Papa (80% and 60%) as good, respectively.

Moreover, Sánchez (2018) analyzed the organoleptic properties of tubers from different commercial yam (*Dioscorea* spp.) clones at 0 and 60 days for the taste and look of boiled tubers. The best results were found in Chino blanco at 0 days (90% excellent and 10% good), followed by Criollo and Papa (70% excellent), Caraqueno (70% good), and lastly, Caballo (90% average). However, at 60 days, the experts chose Chino blanco (70% excellent), followed by Papa (50%), Caraqueno and Criollo (40%), and lastly, Caballo (40%). Similar results were reported by Hidalgo (2014), upon a characterization of the nutritional quality of the yam tubers (D*ioscorea* spp.) through different analysis techniques, with the highest values observed in Chino blanco (70%, as excellent and 30% as good), followed by Criollo and Papa (80% and 60%, as good, respectively).

All the experts wished to consume clones Criollo, Chino blanco, Blanco de Guinea, and Papa, because of their high levels of acceptance and excellent taste, followed by Caraqueno and Caballo with adequate taste, though the latter is not always desirable.

As shown in Table 2, Caballo is part of the traditional diet all over Cuba, due to its rusticity, biotic and abiotic stress tolerance, and the high capacity of natural propagation through bulbs; it has an adequate taste, though it looks rough with a hard texture, making it far from desirable for consumption at all times, but only occasionally. Approximately 50% of the clone is used for seed; the area near the proximal is fibrous, and cannot be used commercially, as usually done by the inexpert farmers or salespeople, causing the refusal by most of the people at the market. Accordingly, this crop must be diversified using promising clones with an excellent agronomic, commercial, and nutritional quality.

Table 2. Organoleptic analysis of diet preparations using different yam clones in Jiguani, Granma, Cuba

Clones	Taste	Look	Texture	Consumption
C	G	A	Hard	Occasionally
Cq	G	G	Soft	Always
CB	E	E	Semi-hard	Always
ChB	E	E	Soft	Always
BG	E	E	Semi-hard	Always
Pa	E	E	Soft	Always

CB, Criollo blanco; ChB, Chino blanco; C, Caballo; Cq, Caraqueno; Pa, Papa; A, Average; G, Good; E, excellent

Likewise, Sánchez (2018) said that the experts' desire to consume boiled tubers from different yam (*Dioscorea* spp.) clones again, was especially strong at 0 and 60 days for Chino blanco, the preferred one, with 100% wishing to consume it again always, followed by Papa, Caraqueno, and Criollo (80%), then Caballo, with 80% of experts never wanting to consume it.

Among the roots and tubers used for human nutrition, yam has a high nutritional value, being cultivated for over 2000 years. It provides around 200 calories in the daily diet of more than 300 million people in the tropical areas (Balogun et al., 2014). It is an excellent source of carbohydrates, mineral salts such as calcium, iron, and phosphorus, and it contains certain levels of vitamin A and C, as well as vitamin B1 or thiamine, which is essential for children's growth, and vitamin B5, important for the immunological system. It also contains riboflavin, niacin, ascorbic acid, pyridoxine, and carotenes. The tubers have most essential amino acids, such as arginine, leucine, isoleucine, and valine, along with histidine, tryptophan, and methionine in lesser amounts. Yam has little fat, and it stimulates the appetite, and cleans the blood (González, 2012).

Conclusions

The process of sensitization and training of 700 people enabled the successful implementation of the biotechnological innovation consisting of accelerated production of certified yam seed (drought resistant) locally, in urban, suburban, and household farming, in the municipality of Jiguani.

The certified seed production reached 6000; they were distributed to outstanding farmers selected in the municipality of Jiguani for cultivation in 0.6 ha, under dry-land conditions.

The organoleptic analysis were found in Criollo, Chino Blanco, and Blanco de guinea, followed by Caraqueno and Papa.

Recommendations

To promote adequate implementation of the biotechnological innovation from CEBVEG for sustainable development of the promising yam clones Criollo, Chino blanco, Blanco de guinea, Caraqueño, and Papa, under dry-land conditions, in the municipality of Jiguani.

Author contribution statement

Diana María Reyes Avalos: Research planning, template mounting, analysis of the results, redaction of the manuscript, final review.

Misterbino Borges García: : Analysis of the results, redaction of the manuscript, final review.

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